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Shaping Digital Transformation – Digital solution systems for the transition to sustainability

A study commissioned by
Huawei Technologies Deutschland GmbH

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Executive Summary

2020 **marked the beginning of a decisive decade** for both Germany and the world as a whole. Over the coming years, we must set a new course to limit global warming, reduce resource consumption, and preserve biodiversity.

Now is the time to act. Efforts to reduce greenhouse gas emissions must be accelerated to achieve net-zero emissions by 2045. **Incremental progress will not be enough.** Every key area of our economy and society must profoundly transform to become more sustainable.

Transformation in these "arenas" will only be possible through digitalisation.

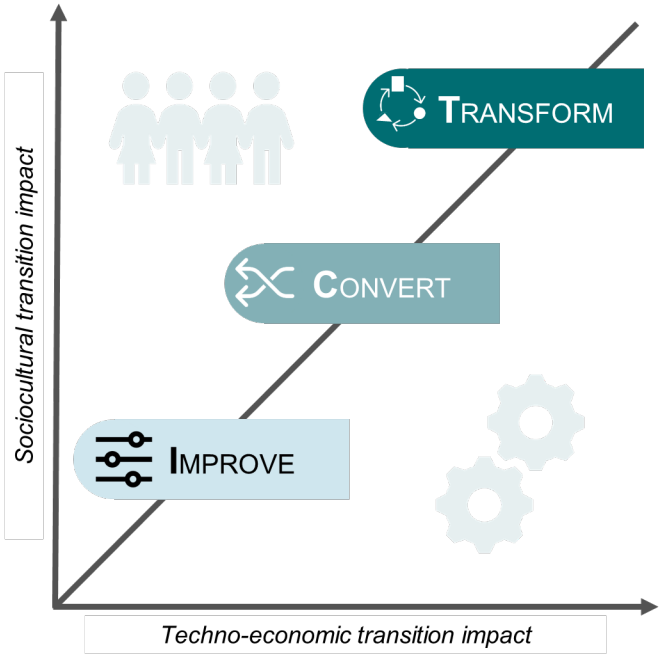

Figure 1: The impact of digitalisation on sustainability transformation

The first step of complete transformation will be utilizing digital technologies and applications to improve current procedures, processes, and structures **(Improve**). Next, complete digitalisation will pave the way for new business models and framework conditions (**Convert**). Finally, comprehensive transformation of the economy and value creation will ensure the effective reorientation of society and lifestyles towards sustainability (**Transform**). This last step is critical for a successful ecological transformation, or a "green transformation", must be placed front and centre during international debate.

Through this report, we aim to highlight and discuss the opportunities that digitalisation can bring to Germany. In particular, we will discuss three exemplary areas of ecological transformation where action is necessary:

A digital and circular economy that uses data to increase resource efficiency: Digitalisation and data are prerequisites for a circular economy. For example, digital product passports and artificial intelligence (AI) analysis tools are helping to identifying materials during recycling. We should ultimately be aiming to share the data gathered from the circular economy in a Circular Economy Data Space, but such a space has yet to be created.

Intelligent, sustainable mobility that connects us in eco-friendly ways: Digitalisation is the key to linking and scaling "EcoMobility" initiatives, use cases, and marketable solutions that combine non-motorized and public transportation. Connected information systems for holistic traffic control and coordination across different transportation methods to achieve services like guaranteed transfer possibilities, will be important as we shift away from our over-reliance on privately owned motor vehicles and towards environmentally sustainable mobility.

Transparent transitions towards sustainable food chains and agriculture: Digital tools and support systems will change our everyday eating habits and lifestyles by providing consumers with more information, guiding purchase decisions, and helping reduce food waste across the entire industrial production chain. Shared platforms and data spaces present new opportunities for reducing environmental burdens in different regions by creating networks of farms. New solutions are emerging that will allow us to better monitor and protect biodiversity and ecosystems, which will drive further sustainability and development within our agricultural policy incentive systems.

However, all of this potential is pinned on **an intelligent, cooperative, and collaborative approach to data (Data Intelligence)**. Data Intelligence will be particularly important in digital solutions between commercial players (B2B solutions), Industry 4.0 approaches, and the Internet of Things (IoT). The process of digital transformation itself, and the technologies, infrastructure, and business models it utilizes, must be compatible with green transformation. **Minimizing the environmental impact of digitalisation** is a key component of green transformation. Examples of green digitalisation include climate-neutral data centres and consumer electronics designed to reduce resource consumption.

This report represents the first phase of our "Shaping Digital Transformation: Digital solution systems for the transition to sustainability" project. In this report, we will outline the framework of our project to create a starting point for further debates. In the second phase of the project, we will host expert workshops that will together explore and define the problems found within the areas of action defined above and identify any additional areas that require concrete action. Throughout this process, we will continue to define the perspectives, insights, and options required to design the political framework and incentive systems the world will need for green transformation.

Starting point: Where Do We Stand?

The 2020s will be a decade of unique environmental challenges. The pressure from climate change has continued to mount, while the progress we have already made in climate protection, resource consumption changes, and biodiversity preservation continues to be insufficient. It is becoming increasingly clear that we must act swiftly and decisively if we want future generations to enjoy the blessing of the natural world. This action will require the right guidelines and framework at the political level, and consistent transformation of both the economy and society.

At the same time, digitalisation is driving fundamental socio-economic transformation processes. New technologies, applications, and business models are changing the way we live our everyday lives, bringing our society closer together and reshaping our economy. The Covid-19 pandemic has highlighted these changes, as we have seen a boom in new forms of virtual communication like telework and home offices. The pandemic has also highlighted clear deficits in our society, particularly in the lack access schools and municipal organizations have to digitalisation resources.

It is time to understand what challenges we will face when forming a green economy and shaping sustainable digital transformation. These to topics are the opposite sides of the same coin, and so they call for an integrated approach that takes into account mutual interdependencies and common opportunities to take action. It will be joint effort, as the European Commission stated when defining the twin transition (European Commission, 2020), that will drive its new Industrial Strategy.

In other words:

> *The enormous scope for shaping digitalisation as a formative force of the 21st century must be at the service of sustainable development, as the most pressing design task of the 21st century.*

As we face down this compelling call to action, there are two key aspects to be considered:

1. **Time is pressing.** A recent ruling by Germany's Federal Constitutional Court on the Climate Protection Act of April 2021 once again underlined the urgency of this situation as reiterated in the latest IPCC report (IPCC, 2021). The profound measures necessary to ward off irreversible consequences cannot be delayed any further. In fact, the Court insisted that efforts to reduce greenhouse gas emissions must be further accelerated to achieve the new 2045 climate neutrality goal (**Figure 2**).
2. **Incremental progress is not enough.** Reducing the impact of global warming will require bold action and fundamental changes. The transition to a fully renewable energy supply, a climate-neutral economy and society, and drastic reductions in global resource consumption are three targets that must be achieved. This will require fundamental changes to every part of the world around us, through a comprehensive reorientation of key areas in both the economy and society which the German Advisory Council on Global Change has called the "Great Transformation" (WBGU, 2011).

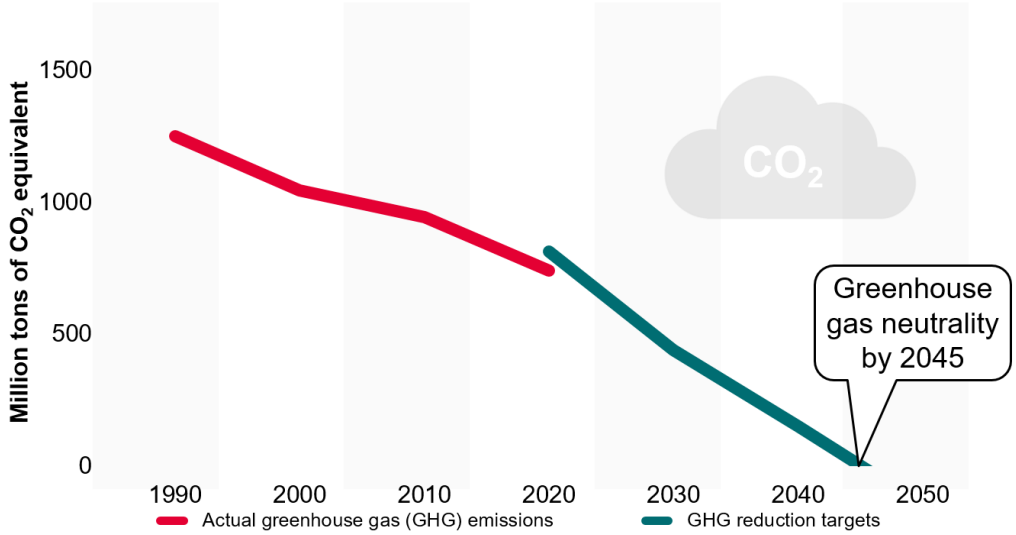

Figure 2: Climate neutrality roadmap (Source: Own illustration based on BMU, 2021)

Citizens, businesses, and policymakers are all facing enormous tasks. Green transformation will require businesses to develop new, sustainable infrastructures, economic systems, and value creation networks. Policymakers will have to create conducive political frameworks, conditions, and incentives. Finally, everyone will have to work together to transform our sociocultural playing field. In practice, this means digitalisation must be carried out in a way that has positive effects on sustainability. We cannot allow digitalisation efforts to reinforce unsustainable behaviour patterns or economic practices that damage the environment and exacerbate the current environmental crisis. Digital transformation itself, i.e. its technologies, infrastructures, and business models, must be sustainable by design, and the environmental impacts of digitalisation must be minimized.

This is where the *"Shaping Digital Transformation: Digital solution systems for the transition to sustainability"* project comes in.

We will determine the specific transformation potential digitalisation brings. We want to create a better understanding of how digital solutions can contribute to profound changes in incentive systems, market structures, business models, and even the behaviours of different stakeholders. Throughout this project, we highlight how these changes can permanently align with climate protection and sustainability.

As such, we will focus on three primary action areas where digitalisation can support necessary, essential transformations:

- The reorientation of traditional industrial production systems and value chains to build resource-efficient, circular economies
- The transition in personal transportation that replaces private car use with innovative, climate-friendly EcoMobility
- New models and incentive systems for sustainable agriculture and nutrition

By focusing on the potential and the necessary requirements for transformation in these three areas, we hope to guide discussions on the sustainability of digitalisation in new directions. The project will push us past the current focus of this debate which primarily revolves around inspiring applications of digital technology in specific processes, particularly by SMEs, and general, summary estimates regarding the impact of digitalisation will have on climate change.

The project will focus on actions at the national level in Germany. Digitalisation is undoubtedly a global phenomenon, but transformation happens locally. Digitalisation must be built into the organization of local actors, local political frameworks, and local discourse and values. When appropriate, the project will also explore the implications and interactions local action will have on European and international initiatives.

This report is only the starting point of the project. It will provide an outline for our future framework and approach, and set the direction of further debates. The three areas of action we have laid out here have only been described in brief to make way for the actual discussions to come. In the second half of 2021, we will perform more in-depth analysis and search for more concrete steps, to take based on the upcoming series of events featuring different actors and stakeholders. The results of this research will be published in separate reports. The project will conclude with a final report reviewing all of our findings.

Perspective: Digitalisation is Key to System Transformation

Digitisation is the translation of information from the physical world into electronic signals. It is a prerequisite for **digitalisation** and fundamentally enables the decoupling of information from the limitations of time and space, thus giving unlimited information usability. This digital mapping of the world is becoming increasingly accurate. Under Industry 4.0, for example, digital twins for plants and processes enable comprehensive optimization within virtual environments. In addition, information availability is now the basis for new sustainable services, such as in local sharing or repair economies.

Digitalisation is characterized by extremely dynamic innovation, especially in key technologies such as sensor technology, data transmission, and chip technologies, as well as in certain types of data analysis such as artificial intelligence processes. Technological progress is rapidly changing the way data is collected, connected, shared, analysed, and used for decision-making and interventions in the physical world. New applications are constantly emerging, and the scope of these applications is ever-expanding.

Digital technologies and applications are critical to green transformation since they are capable of radically changing the way we organize work, production processes, human behaviour, and business models (Figure 3). These radical changes are where the greatest opportunities lie, and so we must seize them while we can. These changes are also closely linked to our three key areas of action.

Digital solutions must be seen as socio-technical innovations that we will use to shape sustainable economies, societies, and politics.

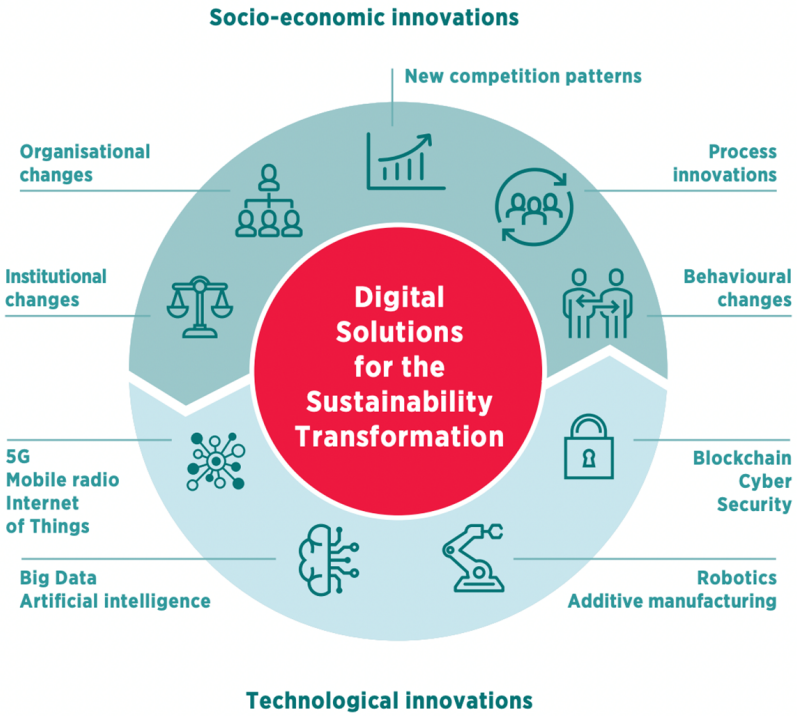

Figure 3: Digital solutions as socio-technical innovations (Source: Ramesohl & Berg, 2019)

Examples: Digital Solutions in Three "Transformation Arenas"

Over the next few years, society will have to create conditions that enable us to organize our lives and economies within the framework of the Sustainable Development Goals. Achieving this will require a fundamental change of direction in all key areas of action across all sectors. For structure, we refer to the 'Transformation Arenas": energy, resource, and water management; mobility; consumption; city management; agriculture; nutrition; education; and health. These sectors are all currently waiting on comprehensive system transformation in terms of political frameworks, incentive systems, market structures, infrastructures, value chains, and behaviours (Schneidewind, 2018). Next, we will discuss three of these transformation arenas, their key challenges, and strategic approaches for ecological change that will benefit from digitalisation. The highlighted digital solutions will illustrate the potential and specific contributions that digitalisation can make to green transformation.

Example 1: A digital and circular economy that use data to increase resource efficiency

German industry must drastically reduce and ultimately completely eliminate its greenhouse gas emissions from production to achieve climate neutrality by 2045. The transition to a resource-conserving, circular economy is the core strategy of a sustainable industrial transformation and an indispensable prerequisite for industrial climate neutrality (Kadner et al., 2021; Sun et al., 2021). The goal of a circular economy is to decouple economic value creation from material resource consumption and, ultimately, to absolutely reduce the flow of physical material, any associated environmental impacts, and greenhouse gas emissions. The key elements of a circular economy can be summarized as the "10R" strategy (**Figure 4**).

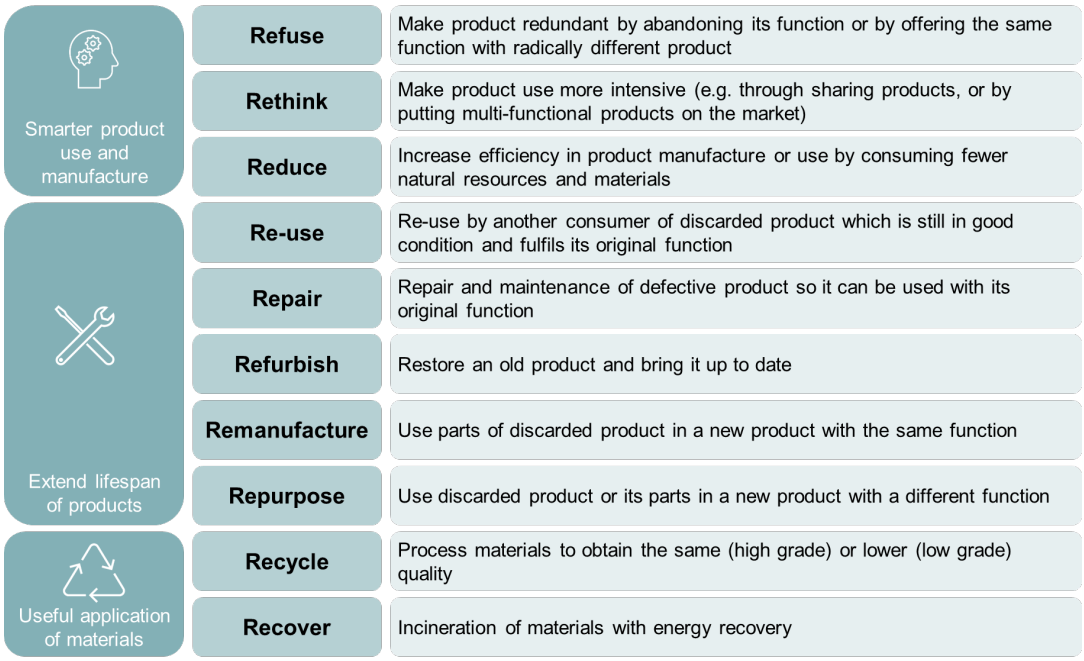

Figure 4: The "10R" strategy for a circular economy (Source: own illustration based on European Environment Agency et al., 2020)

Any vision of a circular economy assumes a paradigm shift in industrial production logic that would have major consequences for all actors and all stages of value creation. Within a circular economy, a value chain becomes a value creation network. In such a network, decisions made at each process stage will affect the options of other actors, and the resulting interactions must be taken into account.

Accordingly, a circular economy must adopt a holistic strategic view of all relevant actors and requires framework conditions that will incentivize the reorganisation and optimisation of the industrial system throughout all process steps and value creation stages. This poses new challenges for all stakeholders from companies, public authorities, and those in politics, as well as for us as consumers.

Digitalisation creates the conditions for mastering these challenges (**Figure 5**):

- Every stage of the circular economy generates data. Combined into and made available through a **Circular Economy Data Space,** such data sets are the prerequisites for comprehensive optimisation strategies. With suitable data structures, trustworthy access management, and effective data governance rules, information from different actors can be linked and shared. This applies to specific segments of a B2B supply chain as well as to aggregated views of sectors and industries. The latter can serve as the basis for the overall monitoring of status, trends, and successes, as well as apparent shortcomings during the transition to the circular economy.
- **User-friendly information** within digital product passports can help customers and service providers use and repair products, opening up new opportunities, business models, and services options. Access to digital design data combined with technologies such as 3D printing creates new options for spare part supply and improves both the reparability and lifespan of many products. Information related to proper disposal, disassembly, and recycling can be stored on product passports.

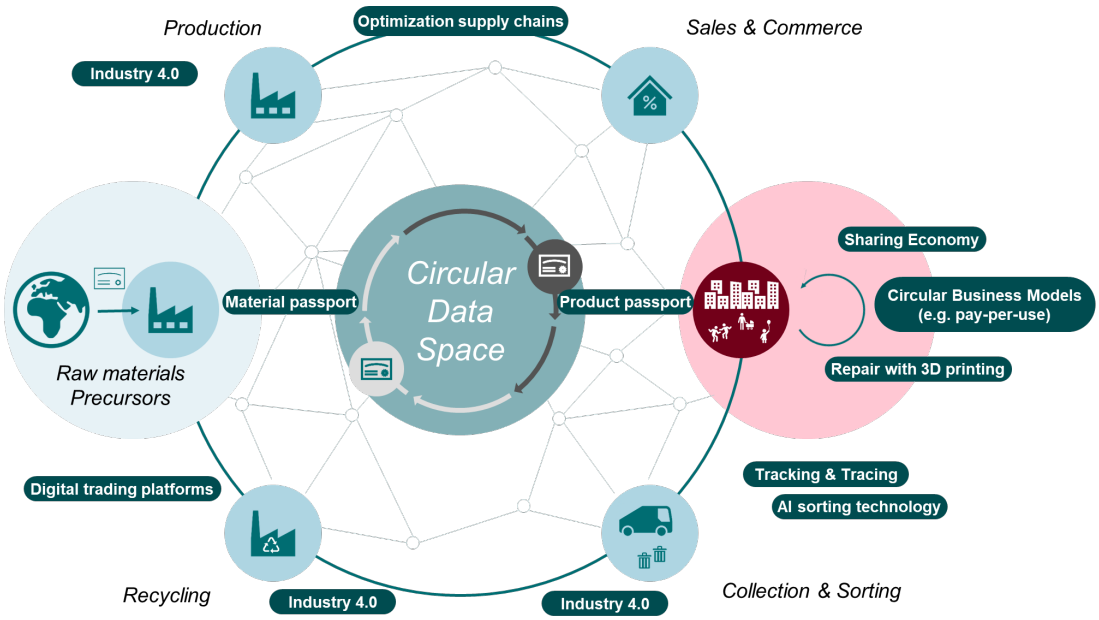

Figure 5: Starting points of digital solutions for the circular economy (Source: own illustration)

- **Digital tools enable new pay-per-use business models** where provider earnings are based entirely on actual product use. Ideally, this will shift the responsibility for product maintenance from the user to the producer and incentivize longer product lifespans. Digital platforms also enable the joint use of products through sharing economies, which can reduce overall resource consumption.
- The broad **portfolio of Industry 4.0 solutions** that currently exists, is already creating new opportunities to optimise industrial processes at all stages of production, as well as for waste management, waste collection logistics, and for sorting and recycling plants (Berg et al., 2021). The evaluation of material flows, usage patterns, and actual recycling processes quality provides important information that can be used to incorporate resource conservation into the product design process. This is called circularity by design. For example, considering future disassembly is already a standard part of the design phase of many products and can be simulated with digital twins.
- **Machine-readable information on material and packaging** facilitates the tracking and identification of material flows (track and trace) to improve recycling operations and support the recycling industry similar to how sorting technologies based on artificial intelligence (AI) are being used.
- **Digital trading platforms** are important channels for marketing quality-tested and certified secondary materials (recyclates) and creating networks between producers throughout the recycling industry.

Starting points and examples of resource-conserving products and processes are now visible in many areas, and this topic is becoming increasingly important. It is yet to be determined how data sharing and common usage will be practically implemented in the Circular Economy Data Space. It also remains unclear how this sharing and common usage can actually drive transformation towards circular and resource-conserving business models and services. These open questions will be addressed in this project's forthcoming report that will take a deeper dive into the circular economy.

Example 2: Intelligent, sustainable mobility that connects us in eco-friendly ways

Our ability to achieve current climate targets will depend on how successful we are at setting the transport sector on a path that significantly reduces emissions over the coming years. The main focus of any such path must be on passenger car traffic, which is primarily powered by fossil fuels and accounts for the largest share (almost 60%) of transport-related greenhouse gas emissions in Germany (Sach et al., 2020). Therefore, a turnaround in this area is key to increasing traffic safety and quality of life in our cities as well as reducing greenhouse gas emissions, air and noise pollution, and the amount of city space needed for cars.

According to science, the task in front of us is clear: Car traffic must shift as far as possible towards an EcoMobility alliance of climate-friendly mobility services, i.e., interactions between walking, cycling, local public transport (LPT), and long-distance rail (Hochfeld et al., 2017). Sharing services can also play an important role here, such as car sharing, bike sharing, and e-scooter sharing, and other new mobility services, such as flexible on-demand ride pooling (Bauer et al., 2020; Purr et al., 2019).

Vehicles themselves must also become emission-free, primarily by switching to renewable energy sources in combination with electric engines and synthetic fuels. Avoidable traffic loads must be reduced or even eliminated completely.

These goals may be achieved in the short term to encourage more people to work from home and take virtual business trips rather than in-person trips. In the long term, though, sustainable urban planning should be considered to design shorter, environmentally friendly routes for public transport (**Figure 6**).

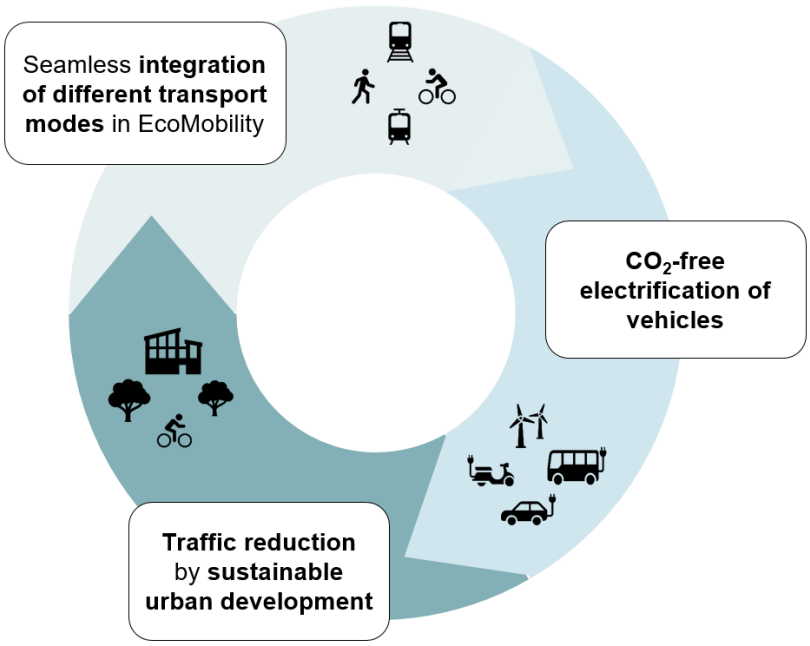

Figure 6: Key points for sustainable mobility in passenger transport (Source: own illustration)

Simply improving automotive technologies will not be enough. Effective climate protection in the transport sector requires a fundamental transformation of the mobility ecosystem. New infrastructural frameworks (e.g., expanding alternatives like rail transport or redistributing road space) must be linked with customer-centric enablers such as new services and innovative mobility solutions. Policymakers should provide regulatory support for this process to avoid "cherry-picking" at the expense of public transport, which would ultimately result in higher car traffic.

Similar to how digitalisation creates conditions that facilitate transformation in the manufacturing industry, transition can deeply benefit from the foundation digitalisation can provide. A powerful and sustainable environmental network that will support local- and long-distance mobility (Figure 7) will need:

- **Integrated user-friendly digital solutions** to plan and execute trips through one-stop platforms for app bundles that complete route planning, payment and billing, and more
- **Interconnected information systems** for holistic traffic control that provide customer information and coordinate different options, like change and connection guarantees
- **Platforms and apps** for additional free-floating sharing offers and on-demand offers, such as ride-sharing, that are integrated into public transport to avoid cannibalization
- **Autonomous and self-driving cars** that have the potential to dramatically change usage patterns for passenger cars, so long as they fit within the outlined transition paths and other parameters used for the last mile of home connections in rural areas

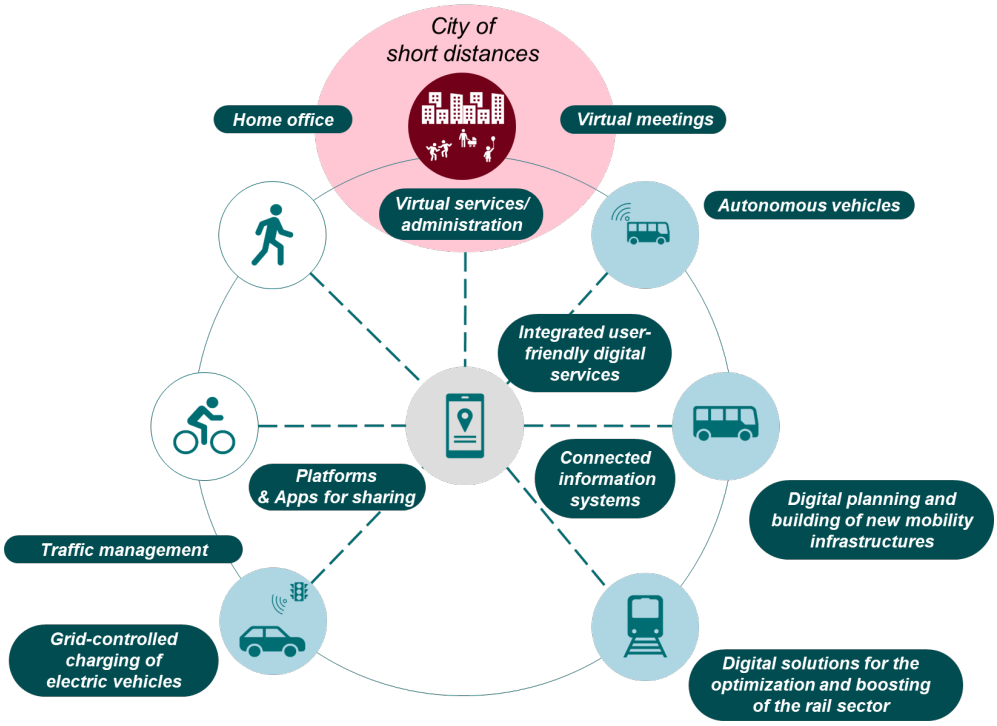

Figure 7: Starting points of digital, sustainable mobility solutions in the environmental network (Source: own illustration)

- **Digital technologies for the upcoming scaling and commercialization of electrical mobility** that can, among other things, operate and manage charging infrastructures, such as a reservation system for charging stations and intelligent solutions for controlled charging that is power grid compatible
- **Increasingly efficient use of space in cities** by using digital solutions to control and optimise car traffic while simultaneously converting and using road space for foot or cycling traffic, or to create new public areas for leisure activities
- Increased infrastructure efficiency through **digital solutions for optimisation in rail transport,** which target higher capacity and reliability to replace short-haul flights[1]
- Positive, new uses for **digital communication media,** like the use of virtual meetings and conferences to encourage changes like working from home and fewer business trips that we saw throughout the Covid-19 pandemic, or the use of virtual administrative offers and services to achieve digitalisation of public authorities and public bodies and reduce traffic.

This initial but incomplete overview gives an impression of how individual digital technologies and applications can contribute to the comprehensive transformation of public mobility and transport systems. First examples, initiatives, innovative prototypes, and even marketable solutions had to be found in many areas (Kampffmeyer et al., 2021). The challenge we face now is scaling these innovations. In following reports, we will explore concrete starting points for key individual elements and determine how to support ambitious political frameworks and incentive structures.

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[1] Within this context, interesting prospects for overcoming bottlenecks arise in relation to the planning and construction of new sustainable mobility infrastructures (e.g. the use of digital twins in digital planning and construction).

Example 3: Transparent transitions towards sustainable food chains and agriculture

Of all the transformation arenas we will explore, agriculture is uniquely dependent on the natural environment. In Germany and across the globe, the agriculture industry has been one of the biggest contributors to environmental problems. Transforming agriculture is not simply about reducing the greenhouse gas emissions of machines, livestock, or fertilizers. True transformation can only be achieved by addressing resource waste, land use, water pollution, animal welfare, and biological diversity.

The way food is produced and processed directly relates to the dietary habits and consumption patterns of all of us as consumers. Any transition in agriculture must be considered in conjunction with a transition in nutrition and vice versa. These interactions must also be considered accordingly.

On the one hand, we must aim to ensure everyone has access to adequate nutrition and a safe food supply. On the other hand, sustainable agriculture will require significant structural changes. We must reward farmers for high-quality and environmentally friendly food production while also remaining committed to animal welfare, nature preservation, and species conservation (Future Commission Agriculture, 2021).

Achieving these objectives will require a profound transformation in agricultural policies and market structures that are currently driven by international competition, price pressure, and effective large-scale production. Therefore, any transformation related to sustainable agriculture and nutrition must start from a few key points. It is also clear that different strategic elements interact with each other, and so continually changing the socio-economic structures of our food supply over the next few years will become vital (**Figure 8**).

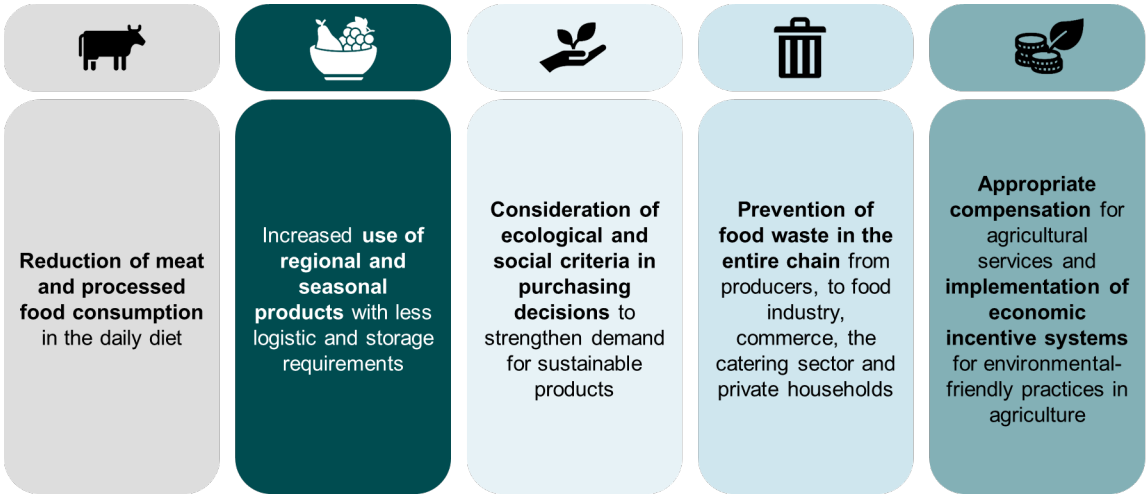

Figure 8: Core strategies for the transition of agriculture and nutrition (Source: own illustration)

Digital technologies support this transition in many ways (**Figure 9**):

- **Digital tools and assistance systems** help change consumer dietary habits and lifestyles by providing more comprehensive nutrition information, supporting decision-making while shopping, and minimizing cooking and kitchen waste. Such systems ensure greater transparency and provide reliable information on the origin of goods, production conditions, and the ecological and social standards of the domestic and global supply chain.

- **Digital platforms and web-based channels** provide customers with alternatives that allow them to shop seasonally and locally through agricultural cooperatives, purchasing groups, and delivery services.
- Innovative local cultivation methods take advantage of **sensors and IoT applications** for irrigation management and so on, expand the world's total arable landmass through methods like vertical farming and urban farming to offer fresh food while shortening supply chains.
- **Data-based forecasting tools** help prevent food waste by optimizing purchases, storage, and sales planning within the retail and hospitality value chains, including in community catering facilities and restaurants. Specially designed platforms and apps can improve the recapture and reallocation of oversupply, reducing food waste. Data-driven and IoT-based solutions for optimizing production processes and logistics are already being used in both the food and retail industries.
- On farms themselves, production is being optimised through **agricultural management systems and precision farming**, which use a combination of weather data, irrigation, fertilization, seed optimisation, and machine management. Sensors, monitoring systems, and data analysis can all help to ensure animal health and welfare. New developments also promise to improve soil cultivation, through actions such as reduced soil compression, by replacing heavy tractors with remote-controlled fleets of small, light, and autonomous agricultural robots.
- **Common platforms and data spaces** are introducing new ways to reduce regional environmental burdens by creating networks of farms. For example, cross-field, ecological optimisation of fertilizers and plant protection products can align with local environmental and weather conditions to increase yield. Digitalisation also allows the use of environmental sensors, drone reconnaissance, and satellite data to **monitor and assess the condition of individual ecosystems** and strengthen the enforcement of environmental regulations and laws.
- As discussed in the recent reforms to the common European agricultural policy, digital applications also play a role in both the **implementation and monitoring of factors that could change the economic incentive systems of agriculture**. Additional eco-schemes, whose ecological requirements stretch beyond mandatory standards, are expected to open new revenues to farms, such as using sown wildflower strips as insect habitats to increase biodiversity.

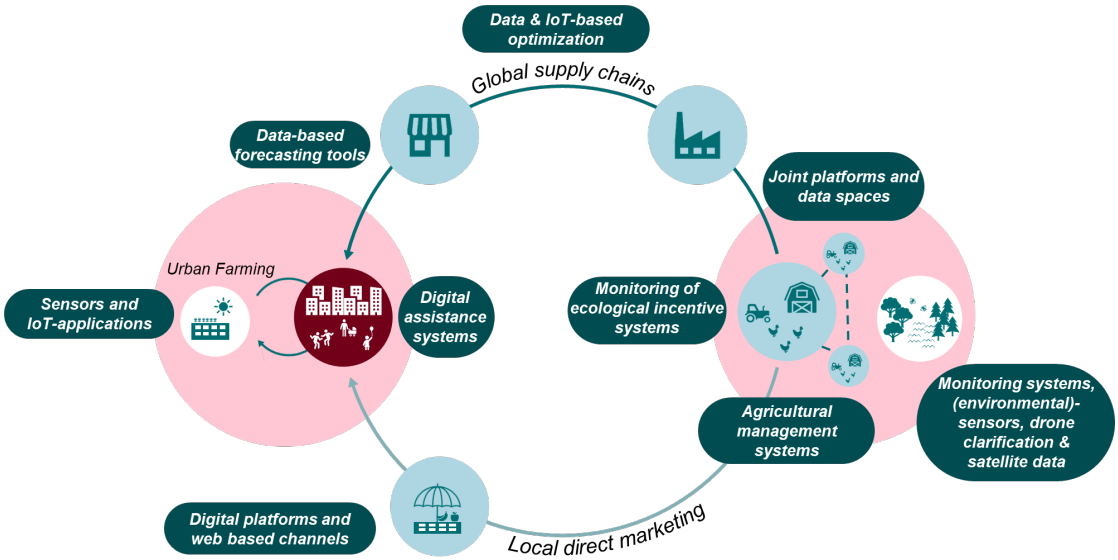

Figure 9: Starting points for digital solutions in the transition of agriculture and nutrition (Source: own illustration)

The above figure shows many aspects of the transition agriculture will have to undertake, but it is still not clear how these building blocks and digital solutions can contribute to a comprehensive transition towards a sustainable agricultural and nutrition ecosystem. In stage of this project, we will continue to explore how the digital technologies of Precision Farming can interact with the digital possibilities of the monitoring and protection of biodiversity and ecosystems in order to, for example, drive the further ecological development of agricultural policy incentives schemes. It will also be important to discuss how digital solutions can help steer individuals towards more sustainable shopping and eating habits.

Challenge: Minimizing the Environmental Impact of Digital Solutions

The preceding sections outlined the possible role digitalisation can play regarding transformation within three of our identified transformation arenas. Multiple digital solutions are expanding our knowledge of the current and future state of our environment and creating new opportunities to organize our social and economic processes and structures in a sustainable and climate-friendly manner. These opportunities must be seized.

However, we must always be aware of one thing: Digitalisation itself impacts the environment because it requires digital devices and infrastructure, such as data centres or communication networks. The production, operation, and disposal of these items can have negative environmental impacts:

- Manufacturing, particularly of digital devices and infrastructure, requires the **extraction and processing of raw materials** that are often sourced from ethically and ecologically problematic supply chains.
- The operation of digital devices and infrastructure results in **energy consumption** and **greenhouse gas emissions**.
- The recovery and recycling mechanisms we currently use for digital devices and infrastructure continue to generate a **rapidly growing amount of e-waste** that is of significant environmental concern.

The challenge we face then is clear: *How* can digitalisation be designed in a way that minimizes its negative effects while maximizing the positive effects of related systems.

The discussion surrounding this is already underway and gaining momentum. Points of focus include the climate impact of data centres, and the various political and private initiatives within the digital economy that are aimed at achieving climate neutrality over the next few years. These are steps in the right direction but they will be far from sufficient on their own. Resource utilization during digitalisation is a growing problem that is still underrepresented in the debate. This requires action.

We must not allow digital devices and infrastructure to be considered in isolation. Software design, data architectures, use cases, and digital business models and their commercialization interests will all influence what digital devices and infrastructure we use, how we use them, and how long they last. Therefore, we must **aim to design a sustainable digitalisation system**, which considers all of these components and accounts for their interactions. This is a goal that must be considered by all, not just by data centre operators or smartphone manufacturers. To truly achieve ecologically sustainable digitalisation, every actor within this system must be involved.

Key areas of focus include:

- **Data centres** which form the basis of all internet-based solutions, including cloud services and streaming. Although energy consumption has been decoupled from computing power in recent years, every possible option for reducing energy demand must be exhausted (Bieser et al., 2020; Masanet et al., 2020). This will require efficient server technologies, the optimisation of infrastructure and auxiliary energy, the recapture and reuse of waste heat, increased power utilization, and, ultimately, a complete conversion to renewable energy. AI-based tools can contribute greatly to the energy management of data centres.

- **Communication networks** which create indispensable links between users in a connected digital world. Strategies for the operation and further expansion of fibre optic and mobile networks must become even more oriented towards energy efficiency, resource efficiency, and the completely transition towards using only renewable energy.
- **Digital devices** which have become plagued by short service life in recent years, have become an essential factor in resource consumption during digitalisation. All digital products should adhere to the principles and strategies outlined above and an emphasis should be placed on effective utilization of raw materials to maximize the durability, reparability, and recyclability of digital devices. Bundling multiple functions within an end-user device can reduce overall resource requirements. Product design will also play a key role in product durability; for example, modular construction allows individual components to be easily replaced, potentially allowing individual devices to be used for much longer. Appropriate strategies must also be taken for software updates to reduce software-related obsolescence. Updates that deliver new functions with higher hardware requirements should be separated from security updates. Where applicable, increasing availability of open-source hardware licenses and software code can also lengthen the service life of digital devices by allowing for alternative repair solutions and update choices.
- **Software design and programming** which are both areas with significant unexplored potential for increasing efficiency, e.g., regarding the choice of programming languages and the efficiency of calculation routines (Geiger et al., 2021).
- **Artificial intelligence** (AI) procedures which are becoming increasingly important. They complement previous statistical approaches and big data analytics and offer new opportunities across a wide range of applications. Due to the significant computational effort and power that can be required to develop and train AI models, each AI solution must be focused on sustainability from the outset. This means choosing the right tools or approaches for specific tasks and evaluating what amount of effort is justified to train or implement an AI. Additionally, aspects surrounding the reuse of data sets and existing models, for example, through off-the-shelf AI solutions or as AI-as-a-Service, should be considered.

These points represent important areas of action that can shape sustainable digitalisation. Digital solutions are based on data, and data needs infrastructure. Every time we **use data, there is an environmental impact**. While there are many other challenges facing data governance, especially considering personal data, such as data protection, protection of privacy, and personal rights, and the role of data to accelerate and consolidate unsustainable consumption patterns.

This is a pivotal topic. Within the context of this project on B2B solutions, Industry 4.0 approaches, and IoT, we are focusing on environmental impacts and identified a promising starting point:

> *Data strategies and business models should be oriented towards the intelligent, cooperative, and collaborative handling of data (data intelligence).*

Environmental cost and benefits must always be reflected in all stages of acquisition, networking, storage, and use of data. This will refine our approach to adequate temporal and spatial resolution for data for specific use cases and facilitate dynamic optimisation according to where and when data is ultimately used and processed (i.e., optimising temporal and spatial organisation of the collection, transmission, and processing of data in cyber-physical systems).

Once we have achieved this, the cooperative and collaborative handling of data in thematically structured data spaces making data available to many users could be game-changing. This is where the data strategies of the European Union and also of the German Federal Government come into play. One example of such a data strategy is the *Circular Economy Data Space* in the EU Green Deal. Conceptual, institutional, and regulatory challenges, such as governance, confidentiality, access management, and incentives, must all be overcome to ensure its implementation.

As of right now, it remains unclear how such approaches would compare with previous patterns of data generation, storage, and data use in terms of ecological sustainability. This will be further explored in a later report from this project. Our key aim must be to cement the concept of *Data Intelligence* and make it viable for green transformation tasks.

Outlook: Where to Next?

As the climate debate has gained momentum, the requirements a green transition must meet have changed. The *Fridays for Future* movement has increased public awareness of these issues, and an increasing number of states, including the EU (European Commission, 2021) and Germany (Federal Government, 2021), have created concrete and binding climate protection programs. The total number of medium-sized companies and global corporations setting their own goals and strategies for climate neutrality has also increased.

At the same time, the EU Commission's Green Deal and the German Resource Efficiency Program *ProgRess III* (BMU, 2020) put the protection of resources and the circular economy firmly on the agenda. The economic potential of a circular economy is being more thoroughly explored, particularly in light of the supply chain disruptions and the supply and raw material shortages that were exacerbated by the pandemic. Cities such as Munich and Kiel are even committing to becoming Zero Waste City goals, which they want to realize together with their citizens.

There is a growing willingness to take on major tasks to achieve a green transition, and it is becoming increasingly clear that this is truly possible. Such a transition will only be possible through jointly designed and implemented system innovations that will revolutionize our social and professional lives, as well as the economy.

Digitalisation will be needed to nurture the solutions and environments necessary for such innovation. However, digitalisation must be carried out correctly. Digitalisation must be at the core of an ambitious and consistent policy framework that has clear objectives and binding implementation paths – not only for climate policy but also in areas like resource protection where policies still lack sufficient quantitative targets and parameters as for example the use of secondary materials. Creating signals for ecological costs, such as CO2 pricing, will also play an important role in encouraging and establishing new, sustainable business models.

This report's brief look at the three key areas of action has shown the potential of digitalisation and a number of ways stakeholders can contribute to these efforts while also discussing where some of our challenges lie.

We will be able to use many different digital technologies and applications to improve current procedures, processes, and structures (***Improve***) and pave the way for new business models and framework conditions (***Convert***) (Figure 10). At the same time, however, digitalisation must also be effective to achieve a comprehensive restructuring of our economy and value creation mechanisms to reorient society and lifestyles (***Transform***). This final level of action must be decisive for it to succeed and, in our view, is still not mentioned enough within current debates.

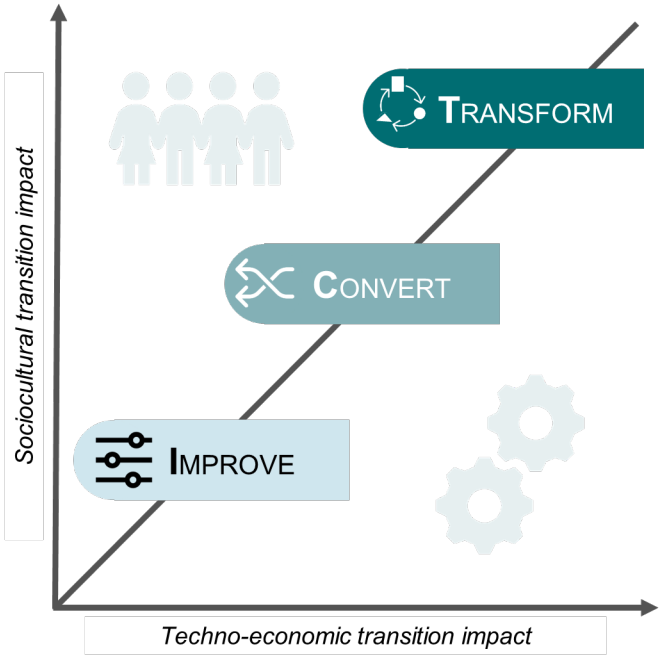

Figure 10: Impact levels of digitalisation on green transition (Source: own illustration)

With this project, we seek to shift the focus of the debate. Specifically, we plan to investigate if and how digitalisation affects the transition to sustainability and identify the individual effects of ICT.

The starting points and guiding questions of this project are:

A digital and circular economy that use data to increase resource efficiency: How can shared data and shared data use be implemented in the sense of the *Circular Economy Data Space*? How can green transformation truly be promoted for circular and resource-friendly business models and services?

Intelligent, sustainable mobility that connects us in eco-friendly ways: How can we network and scale the many existing examples, initiatives, innovative prototypes, and marketable digital solutions for environmentally friendly mobility? How can we support them using political frameworks and incentive structures?

Transparent transitions towards sustainable food chains and agriculture: How can digital technologies like precision farming be combined with digital possibilities to monitor and protect biodiversity and ecosystems? How can they drive green development of agricultural policies and incentive systems?

We want to devote ourselves to these questions in the second phase of this project, refine our research questions and identify any previously unrecognized opportunities to take concrete actions. However, we cannot do this alone. By the very nature of the task, different actors and stakeholders from the economy, society, environmental organizations, and the fields of science, politics, and administration, must come together to determine common objectives and implementation paths.

New interdisciplinary and collaborative formats and discourses are required for both the proposed transitions and the management of the environmental effects of digitalisation. Ultimately, this project is about working together to identify potential, understanding success factors, creating boundary conditions and prerequisites, and guiding entrepreneurial and private actions.

The next phase of the project, which will last until the beginning of next year, shall therefore build on a sequence of events that focus on the three transformation arenas outlined in this report. During these events, we will work together with other experts to contribute to this discussion. In addition, the perspectives, key points, and options related to the necessary design of the German Federal Government's new political framework will be documented.

The discussion on the three transformation arenas shall be complemented by an additional activity during which we will discuss the requirements and opportunities for climate-friendly and environmentally friendly digitalisation, as discussed earlier. During this activity, we will focus on the validity of the outlined concept of intelligent, cooperative, and collaborative data handling (*Data Intelligence*), especially within the context of B2B solutions, Industry 4.0 approaches, and IoT in the three transformation areas.

We expect these efforts to result in new, exciting, and supportive additions to the discussion on sustainable digitalisation.

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